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Research Article

Seasonal Distribution of Ephemeroptera (Insecta) Fauna and Relationship Among Physicochemical Parameters in the Ceyhan Basin

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ABSTRACT

This study was carried out in 20 different localities in the spring, summer and autumn periods in 2019 in order to determine the Ephemeroptera fauna of the Ceyhan Basin and to reveal its relationship with some physicochemical parameters. As a result, 971 specimens were examined and 17 species belonging to six families were identified. There is no data on the given taxa in the Ceyhan basin so all taxa are new records for the Ceyhan Basin. According to the Shannon-Wiener (H) diversity index, the highest and lowest diversity values were determined, respectively, in the spring at stations 7th (1.456) and 6th (0.173), in the summer at stations 20th (1.311) and 13th (0.341), and in the autumn at stations 15th (1.102) and 8th (0.457). According to Evenness (E) values, the most homogeneous stations are the 3rd (0.963), 7th (0.973) and 1st (0.945) stations in the same seasonal order, and the stations with the least homogeneity are the 16th (0.529), 16th (0.659) and 8th (0.527) stations. According to cluster analyses, the highest similarities were observed between stations 3rd and 5th in addition to stations 9th,14th,17th,18th and 19th with 100% percentage. Based on the physicochemical parameters measured in accordance with the Surface Water Quality Regulation, the water quality classes of the stations were in high quality water (Class I) and less contaminated (Class II) water. Canonical correspondence analysis was applied to reveal the relationships between Ephemeroptera taxa and physicochemical parameters.

Keywords: Ephemeroptera, Ceyhan Basin, diversity, water quality, fauna

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INTRODUCTION

Recently, overexploitation of water resources and deterioration of existing water quality are now being caused by a fast population increase, and environmental pressures on aquatic systems due to increasing industrial and agricultural activities (Gelgeç, 2012; Zhang et al., 2019). For this reason, the protection, improvement and sustainable use of water, which is a renewable natural resource, is one of the most important and priority problems (Kalyoncu et. al., 2008; Çiçek & Birecikligil, 2015).

In Turkiye, which is relatively rich in terms of fresh water potential, changes occur in aquatic ecosystems as a result of the negative effects caused by anthropogenic pressures. Accordingly, many groups of organisms react to disturbances in their habitats. As a result, there is a decrease in population densities, changes in habitats and even the extinction of certain species. Thus, changes occur in the species composition of the ecosystem. Depending on these changes in communities, it is possible to evaluate water quality. It is possible to determine the quality of the existing aquatic environment as a result of determining the reactions of aquatic organisms to changes. Biological monitoring is defined as the evaluation of environmental changes caused by human activities according to biological responses in order to evaluate an ecosystem and to identify deviations in its natural structure. (Kazancı et al., 1997). Water quality is an indicator of the physical, chemical and biological properties of water. In studies to determine water quality lotic waters, physicochemical components are not always sufficient because they only reveal the situation at the time of measurement. In this context, biological monitoring is a unifying method in identifying physical, chemical and biological problems, as it more accurately reveals the destructions that occur in sensitive ecosystems. With this method, taxa that can be used as bioindicators (biological indicator) are determined together with the fauna of the studied region. For this reason, physicochemical data should be used together with biological data to evaluate medium and long-term contamination in water quality determination (Uyanık & Cebe, 2017).

Benthic invertebrates in river ecosystems show a great diversity in taxonomic, structural and functional aspects, and each of these living groups has different ecological characteristics (Allan, 1995). Benthic macroinvertebrates are one of the most widely used organism groups in water quality assessment studies because they are sensitive to different chemical and physical conditions. Therefore, the composition of macroinvertebrate species sampled from a water body provides important information for determining the quality of that water body (Hellawell, 1986; Aksoy, 2019).

Ephemeroptera is the most important group among benthic macroinvertebrates with its high species diversity and population density. This order is used as important biological indicators in water quality determination studies, as they are low tolerant to the presence of any pollutant in water bodies and contain many sensitive species against pollution (Özyurt & Tanatmış, 2008; Aksoy, 2019). Ephemeroptera fauna of Turkiye is represented by 34 genera, 138 species and five subspecies belonging to 14 families (Kazancı & Türkmen, 2012, 2016; Salur et al., 2016). In our country, the studies of this order were mostly carried out in the North-West Anatolia region (Tanatmış, 1999, 2000, 2002, 2004a, 2004b, 2007; Kazancı, 2001a, 2001b, 2009; Narin & Tanatmış, 2004; Kazancı & Türkmen, 2008; Tanatmış & Ertorun, 2006, 2008; Türkmen & Özkan, 2011; Türkmen & Kazancı, 2011; Aydınlı, 2013; Küçüker, 2019). There are a very limited number of studies in the remaining parts of Turkiye (Türkmen & Kazancı, 2015; Özgül Uzun, 2018; Bakioğlu, 2019), and in the Seyhan, Ceyhan and Eastern Mediterranean basins, where the rivers flowing into the North-eastern Mediterranean are located, no detailed study has been found so far, except for a few individual studies (Kara & Çömlekçioğlu, 2004; Yıldırım, 2006; Ayas & Kara, 2014).

This study was carried out to reveal the seasonal Ephemeroptera fauna of the Ceyhan Basin and to evaluate the water quality with the help of these parameters by determining the relationships between the identified taxa and the physicochemical parameters in their distribution areas.

MATERIAL AND METHODS

The Ceyhan Basin includes the Ceyhan River originating from the Elbistan district of Kahramanmaraş and the large and small streams that join it, and empties into the sea in the Iskenderun Bay. Field studies were carried out once in the spring, summer and autumn periods at 20 stations determined in 2019. The stations representing the study area and the information about the stations are given in Table 1 and Figure 1.

Sampling and physicochemical parameter measurements of water samples were taken into 1-liter polyethylene containers from the middle of each stream and analyzed in a laboratory environment according to TS EN ISO 5667-3 and TS ISO 5667-6 standards (dissolved oxygen, salinity, total nitrogen, organic nitrogen, alkalinity). Temperature, pH, electrical conductivity were measured and recorded during field studies with the HACH LANGE HQ 40-D portable multiparameter meter.

Benthic macroinvertebrate sampling was carried out by applying 2-3 minutes of kicking method at a distance of 100 m along the stream, with the help of a dip net with a 500 μm mesh, taking into account the different ecological regions of each stream. The obtained benthos samples were transported to Nevşehir Hacı Bektaş Veli University Hydrobiology Research Laboratory in plastic bottles containing 4% formaldehyde solution. The benthos transferred to the laboratory was passed through sieves with different mesh openings and living material was collected with the help of forceps and roughly divided into systematic groups under a LEICA EZ-4D brand stereo microscope. Then, using LEICA DM-500 brand light microscope, they were identified at family, genus and species level. Kazancı (1985); Kluge (1988, 1994, 1997); Tanatmış (1993); Bauernfeind (1994, 1995); Haybach (1999); Bauernfeind & Soldan (2012); Türkmen and Kazancı (2013) were used in the identification of the species.

In the evaluation of biological data; dominance and frequency values of Ephemeroptera order according to stations were calculated by using individual numbers (Kocataş, 1997). The species diversity in the stations according to the detected species was revealed by SHE analysis via BİÇEB software (Özkan et al., 2020), and the similarities depending on the distinction between stations were revealed by two-way cluster analysis using Past-3 and PC-ORD software. In order to eliminate the multicollinearity problem between the physicochemical parameters and to select the appropriate parameters and to determine the relationship between the variables, the multicollinearty test and Pearson correlation analysis were performed using the ECOM-2.01 package program, respectively. The relationship between the determined taxa and physicochemical variables was revealed by Canonical CorrespondenceAnalysis (CCA) using the CANOCO-4.5 software. In addition, the water quality classes of the stations were interpreted based on some physicochemical parameters measured according to the Surface Water Quality Regulation (YSKY, 2021).

RESULTS AND DISCUSSION

The R-squared (R^2) and variance inflation factor (VIF) of the multicollinearity test are presented in Table 2. According to this; The evaluations were continued by eliminating the variables (salinity, organic nitrogen and alkalinity) that had R^2>0.9 and VIF>10 values and were calculated close to these values due to their close relationship with each other.

According to the results of the correlation analysis applied to determine the relationship of physicochemical parameters with each other; statistically, a significant positive correlation was observed between dissolved oxygen and pH, and between total nitrogen and temperature, while a significant negative correlation

Table 1. Information about the sampling stations of the Ceyhan Basin.

Code	Stream Name	Latitude	Longitude	Bottom Structure	Agriculture	Farming
1	Çatağın	36.68033	38.36949	Rock, stone and gravel	Unavailable	Available
2	Tokadun	36.44295	38.07066	Rocks, stones, gravel and coarse sand	Unavailable	Unavailable
3	Fenk	36.51513	37.83089	Rock, stone and gravel	Available	Available
4	Büyükçat	36.40425	37.76909	Stone, gravel and sand	Available	Available
5	Kirksu	36.36456	37.77113	Stone and gravel	Unavailable	Available
6	Topaktas	36.3627	37.70541	Rocks, stones, gravel and coarse sand	Available	Available
7	Hüseyin	36.39426	37.06847	Rocks, stones, gravel and coarse sand	Unavailable	Unavailable
8	Baskonus	36.53387	37.25438	Stone, gravel and coarse sand	Unavailable	Available
9	Zokur	36.55773	37.34633	Rocks, stones, gravel and coarse sand	Unavailable	Available
10	Çağırgan	36.60487	37.39108	Rocks, stones, gravel and coarse sand	Available	Available
11	Keven	37.03649	37.79895	Rock, stone and gravel	Unavailable	Unavailable
12	Karataş	36.77581	37.90035	Rocks, stones, gravel and coarse sand	Available	Available
13	Kızıldağ	36.75949	37.94049	Rock, stone and gravel	Unavailable	Available
14	Geyikbeli	36.95934	37.98516	Rocks, stones, gravel and coarse sand	Unavailable	Unavailable
15	Söğütlü	37.63291	38.11674	Rocks, stones, gravel and coarse sand	Available	Available
16	Pasaölen	36.58571	38.23852	Stone, gravel and sand	Unavailable	Available
17	Mahmut	36.99009	38.4868	Rocks, stones, gravel and coarse sand	Available	Available
18	Çamlı	36.31581	37.76583	Stone and gravel	Available	Available
19	Kuru	36.34822	37.75084	Rocks, stones, gravel and coarse sand	Available	Available
20	Kirazlı	36.4	37.64492	Rocks, stones, gravel and coarse sand	Unavailable	Available

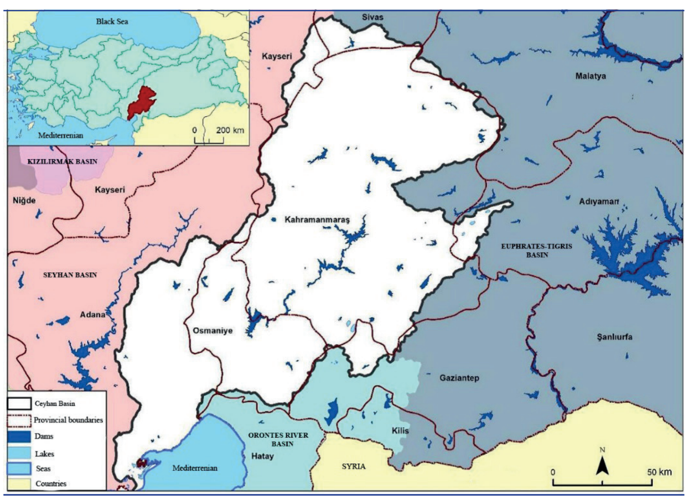

Figure 1. Location map of the Ceyhan Basin.

was observed between dissolved oxygen and temperature and total nitrogen (p<0.01) (Table 3). Seasonally, physicochemical parameters and quality classes of the stations are given together with their color coding in Table 4 (YSKY, 2021).

According to Table 4, when the water quality classes of the stations are evaluated in terms of some parameters seasonally (YSKY, 2021); In all three periods, it has been determined that all stations have first class water quality according to temperature, pH and total nitrogen. In the spring period, 17th station in terms of dissolved oxygen and 2nd, 7th, 17th and 19th stations in terms of electrical conductivity have second class water quality while the other stations were determined to be of first class water quality. In the summer period; 1st, 5th, 6th, 8th, 11th, 13th, 17th, 18th, 19th and 20th stations in terms of dissolved oxygen, 2nd, 3rd, 4th, 7th, 9th, 17th, 18th and 19th stations in terms of electrical conductivity have second class water quality while the other stations were determined to be of first class water quality. In the autumn period, measurements could not be made at the 4th, 10th, 11th and 17th stations due to the dryness of the water, and 3rd, 5th, 7th, 9th, 12th, 14th and 20th stations in terms of dissolved oxygen and 2nd, 3rd, 7th and 19th stations in terms of electrical conductivity have second class water quality while the other stations were determined to be of first class water quality. If the final classes of the stations regarding the average values of the parameters are evaluated; while 2nd, 3rd, 4th, 7th, 17th and 19th stations have moderate polluted water quality, the other stations are determined to be in high quality water class. Accordingly, it can be said that all stations are in a healthy ecosystem structure and there is no element that threatens the water quality.

As a result of sampling at 20 stations in three different periods, 971 individuals were examined and 17 species belonging to six families (Baetidae, Heptageniidae, Leptophlebiidae, Ephemeridae, Ephemerellidae and Caenidae) were identified (Table 5). Considering the seasonal dominance of the species (%), the most dominant species is *B. rhodani* with the rates of 56.49%, 58.36% and 81.05% in the spring, summer and autumn periods, respectively, *E. alpicola* followed with a rate of 23.32% and 13.5% in the spring and summer periods, *E. lateralis* and *R. semicolorata* followed with a rate of 3.68% in the autumn period. Considering the frequency values (%) of the species, *B. rhodani* is the most common taxon with 90%, 85% and 65% rates in the spring, summer and autumn periods, respectively, while it was followed by *E. alpicola* with 40% and 30% rates in the spring and summer

Table 2. Multicollinearty test of physicochemical parameters.

Dependent variable	R-squared	VIF
Temperature (°C)	0.657	2.919
pH	0.295	1.418
Electrical Conductivity (µS/cm)	0.796	4.905
Dissolved Oxygen (mg/L)	0.715	3.503
Salinity (%)	**0.929**	**14.01**
Total Nitrogen (mg/L)	0.336	1.507
Organic Nitrogen (mg/L)	**0.973**	**36.643**
Alkalinity (CaCO3 (mg/L))	**0.795**	**4.877**

Table 3. Pearson correlation of physicochemical variables.

	Temperature (°C)	pH	EC (µS/cm)	DO (mg/L)	TN (mg/L)
Temperature (°C)	1				
pH	-0.026	1			
EC (µS/cm)	0.219	0.054	1		
DO (mg/L)	**-0.744**	**0.369**	-0.097	1	
TN (mg/L)	**0.479**	0.005	-0.115	**-0.484**	1

The correlation is significant at the p<0.01 level. EC: Electrical Conductivity, DO: Dissolved Oxygen, TN: Total Nitrogen

periods respectively, and *E. alpicola*, *E. lateralis* and *R. semicolorata* with the same frequency (10%) in the autumn period (Table 6). The continuous presence of *B. rhodani* in all three periods indicates that the ecological tolerance of the species is high.

In studies on ecology based on diversity calculation, Shannon-Wiener species diversity index (H) has become a more preferred index in ecology as it gives more objective results without distinguishing rare and dominant species (Gülsoy & Özkan, 2008; Özkan et al., 2020). For this reason, the SHE analysis, which is a technique in which the number of species (S), Shannon-Wiener species diversity index (H) and equality-balance (E) results were presented simultaneously. According to the data obtained from the sampled Ephemeroptera taxa and the abundance values of the individual numbers, when the general diversity status is examined regardless of the season; the species richness was highest with eight and six species at the 7th and 15th stations, then four species with the same species richness at the 1st, 8th, 10th, 12th, 16th and 20th stations and three species with the 2nd, 3rd ,5th and 13th stations was observed. The stations with the least species diversity were determined as the 4th and 6th stations with 2 species and the 9th, 11th, 14th, 17th, 18th and 19th stations with only one species.

According to the results of the SHE analysis (Table 7 and Figure 2); if the H values that express the diversity are compared; in the spring period, the highest diversity was calculated at the 7th, 20th and 15th stations with the values of 1.456, 1.199 and 1.158, respectively, and the lowest diversity was calculated as the 6th and 4th stations, with the values of 0.173 and 0.245, respectively. The highest E values expressing balance-equality were calculated at the 3rd and 13th stations with 0.963 and 0.877, respectively, and the lowest values were calculated at the 16th and 7th stations with 0.529 and 0.536 respectively. The differences in the diversity (H) values of the stations that have the same species richness but differ in terms of individual numbers, or the disproportions in the H and E values of the stations with high species richness vary according to the distribution characteristics of the taxa at the stations. Therefore, although the species richness of the 20th station and the 15th, 10th, 12th and 16th stations are the same, the higher H value of the 20th station explains the high level of balanced distribution among the species found there. As a matter of fact, it is seen that the E value, which expresses balance-equality, is higher at the 20th station. On the other hand, it has been observed that the 7th station, which has the highest species richness, has a low E value against the high H value. This is explained by the less balanced (heterogeneous) distribution of individuals in that station.

In the summer sampling period, the highest H value was calculated with 1.311, 1.210 and 1.117 at the 20th, 15th and 10th stations, respectively, and the lowest was 0.341 at the 13th station. The stations with the most balanced (homogeneous) distribution were seen as the 7th station with 0.973 according to the results of the E value expressing equality and balance, followed by the 1st and 8th stations with the same value (0.963). The stations with the least balanced distribution were determined as 16th and 12th stations with 0.659 and 0.666, respectively.

In the autumn period sampling, which was completed with the least species diversity as a result of the increase in the species eliminated from the environment due to both the drying up of the waters and the changing water parameters, the highest diversity (H) was calculated at the 15th and 16th stations with the values of 1.102 and 0.843, respectively, and the lowest diversity was calculated at the 8th station the value of 0.457. The stations with the most balanced distribution were determined as the 1st and 6th stations with the values of 0.945 and 0.877, respectively, and the stations with the least balanced distribution were determined as the 8th and 15th stations, respectively, with the values of 0.527 and 0.753.

Since they have only one species in all three seasons, no significant results could be obtained in stations with species richness of 1, and H and E values were calculated as 0 and 1, respectively (Table 7 and Figure 2). In addition, no samples could be detected at the 1st station in the spring period, the 4th in the summer period, and the 7th and 19th stations in the autumn period.

According to the distribution of the obtained taxa, the similarities between the stations were examined by the Bray-Curtis Analysis method (Figure 3). According to this; among the 20 stations, the highest similarity rate (100%) was observed between the 3rd and 5th stations and between the 9th, 14th, 17th, 18th and 19th stations. This is followed by the similarity of the 3rd and 5th sta-

Table 4. Physicochemical parameters of the stations.

Quality Classes and Stations	Season	Temperature (°C)	pH	EC(μS/cm)	DO (mg/L)	TN (mg/L)
I (High-quality water)	-	≤ 25	6-9	< 400	> 8	< 3.5
II (Moderate polluted water)	-	≤ 25	6-9	1000	6	11.5
III (Polluted water)	-	≤ 25	6-9	>1000	<6	>11.5
1	Spring	11.10	8.86	239.00	8.74	0.71
	Summer	19.60	8.58	252.00	7.52	2.76
	Autumn	10.80	8.11	245.00	8.22	2.22
	Avg.	**13.80**	**8.52**	**245.00**	**8.16**	**1.90**
2	Spring	12.00	8.51	436.00	9.46	0.11
	Summer	17.60	8.40	475.00	8.23	0.47
	Autumn	12.20	7.91	439.00	9.58	0.37
	Avg.	**13.90**	**8.27**	**450.00**	**9.09**	**0.32**
3	Spring	11.90	8.88	250.00	9.12	0.29
	Summer	17.20	8.50	409.00	8.29	1.20
	Autumn	16.10	7.92	434.00	7.84	0.19
	Avg.	**15.10**	**8.43**	**364.00**	**8.42**	**0.56**
4	Spring	11.10	8.60	383.00	10.10	0.1
	Summer	23.60	8.38	444.00	8.06	0.82
	Autumn	-	-	-	-	-
	Avg.	**17.40**	**8.49**	**414.00**	**9.07**	**0.43**
5	Spring	10.80	8.58	288.00	9.28	0.14
	Summer	14.60	8.34	338.00	7.76	0.70
	Autumn	12.40	7.44	331.00	7.92	0.44
	Avg.	**12.60**	**8.12**	**319.00**	**8.32**	**0.43**
6	Spring	11.30	8.61	399.00	9.42	0.1
	Summer	18.80	8.44	396.00	7.60	0.56
	Autumn	16.60	8.82	357.00	8.56	1.28
	Avg.	**15.60**	**8.62**	**384.00**	**8.53**	**0.63**
7	Spring	12.70	8.75	402.00	9.67	1.20
	Summer	18.00	8.74	479.00	8.74	0.38
	Autumn	16.70	8.36	465.00	7.91	0.76
	Avg.	**15.80**	**8.62**	**449.00**	**8.77**	**0.78**
8	Spring	17.70	8.41	153.00	8.45	0.17
	Summer	18.60	8.39	191.00	7.44	0.72
	Autumn	15.90	7.36	200.00	8.35	0.92
	Avg.	**17.40**	**8.05**	**182.00**	**8.08**	**0.60**
9	Spring	16.90	8.89	384.00	9.22	0.1
	Summer	19.10	8.91	415.00	8.63	0.88
	Autumn	18.10	8.60	390.00	7.86	0.45
	Avg.	**18.00**	**8.80**	**396.00**	**8.57**	**0.46**
10	Spring	15.30	8.51	259.00	9.29	0.52
	Summer	19.00	8.51	292.00	8.60	1.81
	Autumn	-	-	-	-	-
	Avg.	**17.20**	**8.51**	**276.00**	**8.95**	**1.17**
11	Spring	16.00	8.75	236.00	8.75	0.49
	Summer	16.90	8.37	277.00	7.61	0.62
	Autumn	-	-	-	-	-
	Avg.	**16.50**	**8.56**	**257.00**	**8.18**	**0.56**
12	Spring	12.20	8.78	345.00	9.60	0.19
	Summer	18.60	8.43	340.00	8.09	1.59
	Autumn	16.30	7.91	396.00	7.84	0.52
	Avg.	**15.70**	**8.37**	**360.00**	**8.51**	**0.76**

Table 4. Continue.

Quality Classes and Stations	Season	Temperature (°C)	pH	EC(µS/cm)	DO (mg/L)	TN (mg/L)
13	**Spring**	8.20	8.84	79.80	9.80	0.21
	Summer	16.10	8.40	91.00	7.58	1.18
	Autumn	16.10	8.40	290.00	8.03	0.50
	Avg.	**13.50**	**8.55**	**154.00**	**8.47**	**0.63**
14	**Spring**	10.40	8.56	161.00	9.96	0.17
	Summer	18.50	8.64	265.00	8.04	1.60
	Autumn	18.30	7.78	237.00	7.65	1.11
	Avg.	**15.70**	**8.33**	**221.00**	**8.55**	**0.96**
15	**Spring**	10.50	8.65	208.00	9.58	0.31
	Summer	16.30	8.50	244.00	8.11	2.18
	Autumn	14.20	7.78	233.00	8.07	1.17
	Avg.	**13.70**	**8.31**	**228.00**	**8.59**	**1.22**
16	**Spring**	9.90	8.50	245.00	9.75	0.63
	Summer	13.60	8.60	270.00	8.67	2.45
	Autumn	14.50	8.34	281.00	8.38	1.50
	Avg.	**12.70**	**8.48**	**265.00**	**8.93**	**1.53**
17	**Spring**	14.30	8.43	442.00	7.24	0.63
	Summer	17.40	8.76	506.00	7.44	1.24
	Autumn	-	-	-	-	-
	Avg.	**15.90**	**8.60**	**474.00**	**7.34**	**0.94**
18	**Spring**	11.60	8.63	319.00	9.34	0.13
	Summer	22.60	8.60	414.00	7.26	2.54
	Autumn	15.90	8.18	385.00	8.53	0.74
	Avg.	**16.70**	**8.47**	**373.00**	**8.38**	**1.14**
19	**Spring**	11.60	8.46	430.00	9.38	0.19
	Summer	19.40	8.38	424.00	7.20	1.42
	Autumn	14.50	7.90	418.00	8.58	0.35
	Avg.	**15.20**	**8.25**	**424.00**	**8.39**	**0.65**
20	**Spring**	11.60	8.54	397.00	9.60	0.12
	Summer	1860	8.41	362.00	7.74	1.49
	Autumn	15.30	7.40	367.00	7.55	0.32
	Avg.	**15.20**	**8.12**	**375.00**	**8.30**	**0.64**

EC: Electrical Conductivity, DO: Dissolved Oxygen, TN: Total Nitrogen, Avg: Average. (In the Autumn period, measurements could not be made at stations 4, 10, 11 and 17 due to the drying up of the waters.)

tions to the 10th and 16th stations with a rate of 86%. The least similarity was determined as the distance of the 15th station to the 12th and 20th stations with a rate of 20%. This was followed by the distance of the 7th station to the 9th, 14th, 17th, 18th and 19th stations and the 13th station to the 15th station, with a rate of 22%. On the other hand, it was determined that the 11th station was the most different station in the basin by being completely separated from the other stations, except for the 40% similarity to the 10th station. The reason for this is that the taxon *H. perflava* could not be detected at any station other than these two stations, and no other species other than this species were found at station 11. As a matter of fact, in the CCA graph obtained, it is seen that this species is located far from the center.

The eigen values of the first two axes were calculated as 0.208 and 0.141, respectively, in the Canonical Correspondence Analysis (CCA) applied to understand the relationship of species with physicochemical parameters. In the graph obtained, the dissolved oxygen, pH and total nitrogen variable groups and the temperature and electrical conductivity variables are located on different axes, and the most decisive variables are determined as electrical conductivity and temperature. *C. macrura* taxon is located at a distant point in the graph, since it was not observed at any station other than station 2 of the autumn period and no other taxa was encountered at this station (Figure 4).

Among the 971 individuals examined, the highest diversity belongs to the Heptageniidae family with 11 species, and the lowest diversity belongs to the Baetidae, Leptophlebiidae, Ephemeridae and Caenidae families, which are represented by a single species. While *B. rhodani* was observed as the taxon with the highest number of individuals with 602 individuals, the least number of individuals was determined in *E. affinis* and *E. assimilis* species with one individual. Considering the species diversity seasonally; 13, 11 and

Table 5. Distribution of the detected species by stations.

	Stations										Seasons		
Family and Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Spr**	**Sum**	**Aut**
Baetidae													
Baetis rhodani (Pictet, 1843)	+	+	+	+	+	+	+	+	+	+	****	****	***
Heptageniidae													
Ecdyonurus macani (Thomas ve Soma, 1970)	+						+				*	*	-
Electrogena lateralis (Curtis, 1834)	+			+			+				*	-	*
Epeorus alpicola (Eaton, 1871)		+	+		+		+	+		+	**	**	*
Epeorus assimilis (Eaton, 1865)							+				*	-	-
Heptagenia coerulans (Rostock, 1877)											*	*	-
Heptagenia perflava (Roctock, 1878)										+	*	*	-
Heptagenia sp.											*	*	-
Rhithrogena semicolorata Curtis, 1834)	+		+		+		+			+	**	**	*
Ecdyonurus submontanus (Landa, 1970)											-	-	*
Electrogena affinis (Eaton, 1886)								+			-	-	*
Epeorus caucasicus (Tshernova, 1938)											-	-	*
Leptophlebiidae													
Paraleptophlebia submarginata (Stephens, 1835)						+	+				*	*	*
Ephemeridae													
Ephemera vulgata (Linnaeus 1758)											*	*	-
Ephemerellidae													
Serratella ignita (Poda, 1761)							+	+			*	*	-
Ephemerella notata (Eaton, 1887)											*	*	-
Caenidae													
Caenis macrura (Stephens, 1836)		+									-	-	*
Total	**4**	**3**	**3**	**2**	**3**	**2**	**8**	**4**	**1**	**4**			

	Stations										Seasons		
Family and Species	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Spr**	**Sum**	**Aut**
Baetidae													
Baetis rhodani (Pictet, 1843)		+	+	+	+	+	+	+	+	+	****	****	***
Heptageniidae													
Ecdyonurus macani (Thomas ve Soma, 1970)						+				+	*	*	-
Electrogena lateralis (Curtis, 1834)			+								*	-	*
Epeorus alpicola (Eaton, 1871)		+	+			+					**	**	*
Epeorus assimilis (Eaton, 1865)											*	-	-
Heptagenia coerulans (Rostock, 1877)		+									*	*	-
Heptagenia perflava (Brodsky, 1930)	+										*	*	-
Heptagenia sp.										+	*	*	-
Rhithrogena semicolorata (Curtis, 1834)					+	+					**	**	*
Ecdyonurus submontanus (Landa, 1970)					+						-	-	*
Electrogena affinis (Eaton, 1886)											-	-	*
Epeorus caucasicus (Tshernova, 1938)					+						-	-	*
Leptophlebiidae													
Paraleptophlebia submarginata (Stephens, 1835)		+									*	*	*
Ephemeridae													
Ephemera vulgata (Linnaeus, 1758)										+	*	*	-

Table 5. Continue.

	Stations										Seasons		
Family and Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Spr**	**Sum**	**Aut**
Ephemerellidae													
Serratella ignita (Poda, 1761)					+						*	*	-
Ephemerella notata (Eaton, 1887)					+						*	*	-
Caenidae													
Caenis macrura (Stephens, 1836)											-	-	*
Total	**1**	**4**	**3**	**1**	**6**	**4**	**1**	**1**	**1**	**4**			

Spr: Spring, Sum: Summer, Aut: Autumn, *: Rare, **: Scarce, ***: Usually, ****: Continuous

Table 6. The seasonal abundance (N/m²), % dominance (D) and % frequency (F) values of the detected Ephemeroptera samples.

	Spring			Summer			Autumn		
Species	**N/m²**	**%D**	**%F**	**N/m²**	**%D**	**%F**	**N/m²**	**%D**	**%F**
Baetis rhodani	235	56.49	90	213	58.36	85	154	81.05	65
Caenis macrura	0	0.00	0	0	0.00	0	6	3.16	5
Ecdyonurus macani	4	0.96	15	20	5.48	20	0	0.00	0
Ecdyonurus submontanus	0	0.00	0	0	0.00	0	6	3.16	5
Electrogena affinis	0	0.00	0	0	0.00	0	1	0.53	5
Electrogena lateralis	4	0.96	10	0	0.00	0	7	3.68	10
Epeorus alpicola	97	23.32	40	48	13.15	30	6	3.16	10
Epeorus assimilis	1	0.24	5	0	0.00	0	0	0.00	0
Epeorus caucasicus	0	0.00	0	0	0.00	0	2	1.05	5
Heptagenia coerulens	2	0.48	5	2	0.55	5	0	0.00	0
Heptagenia perflava	5	1.20	10	16	4.38	10	0	0.00	0
Heptagenia sp.	1	0.24	5	5	1.37	5	0	0.00	0
Rhithrogena semicolorata	41	9.86	30	15	4.11	25	7	3.68	10
Paraleptophlebia submarginata	5	1.20	15	15	4.11	10	1	0.53	5
Ephemera vulgata	3	0.72	15	4	1.10	5	0	0.00	0
Ephemerella ignita	12	2.88	15	18	4.93	10	0	0.00	0
Ephemerella notata	6	1.44	5	9	2.47	5	0	0.00	0
Total	**416**	**100**	**-**	**365**	**100**	**-**	**190**	**100**	**-**

nine species were identified in the spring, summer and autumn periods, respectively. When the stations are compared on a seasonal basis in terms of species diversity, the highest diversity was seen at the 7th station belonging to the spring period with eight species. This was followed by the 10th, 12th, 15th, 16th and 20th stations of the spring and summer periods and the 15th station of the autumn period with four species. Considering the abundance values of the stations, the highest Ephemeroptera community diversity was determined with 69 individuals at the 7th station of the spring period, and the lowest with a single individual at the 2nd and 14th stations of the spring period and the 18th station of the autumn period. Shannon values (H) of SHE analysis used to determine diversity support this result. *B. rhodani* taxon was observed as the most dominant species with 235, 213 and 154 individuals in the spring, summer and autumn periods, respectively, and it was also the most frequently observed taxon by being detected in 18, 17 and 13 stations, respectively.

The high diversity in the spring and summer periods can be explained by the increase in the dissolved oxygen value, which is the appropriate parameters for Ephemeroptera communities -especially the Heptageniidae family-, where diversity is high-, due to the increase in the waters together with the melting of the snow waters, and accordingly the decrease in the amount of pollution and organic matter. The fact that the diversity in the autumn period is low compared to the other seasons is the fact that no sampling can be made at the 4th, 10th, 11th and 17th stations, which have a seasonal stream regime, together with the drying of the waters. On the other hand, it is due to the decrease in available waters and the inability to observe some species (particularly, individuals belonging to the genus Heptegenia and Ephemera, which prefer habitats where the flow is fast, dissolved oxygen is abundant and the amount of organic matter is low).

When some of the physicochemical parameters measured according to the Surface Water Quality Regulation (YSKY, 2021) are exam-

Table 7. SHE diversity analysis values, number of species (S) and individual numbers (N) calculated based on the species and individual numbers of the stations.

Station	S	N	H	E	Station	S	N	H	E
1-Sum	3	14	1.061	0.963	**11-Sum**	1	12	0.000	1.000
1-Aut	2	3	0.637	0.945	**12-Spr**	4	28	0.855	0.588
2-Spr	1	1	0.000	1.000	**12-Sum**	4	30	0.980	0.666
2-Sum	2	16	0.621	0.930	**12-Aut**	1	4	0.000	1.000
2-Aut	1	6	0.000	1.000	**13-Spr**	2	16	0.562	0.877
3-Spr	3	9	1.061	0.963	**13-Sum**	2	28	0.341	0.703
3-Sum	1	3	0.000	1.000	**13-Aut**	2	33	0.474	0.803
3-Aut	1	9	0.000	1.000	**14-Spr**	1	1	0.000	1.000
4-Spr	2	15	0.245	0.639	**14-Sum**	1	11	0.000	1.000
5-Spr	3	40	0.900	0.820	**14-Aut**	1	8	0.000	1.000
5-Sum	1	13	0.000	1.000	**15-Spr**	4	27	1.158	0.796
5-Aut	1	11	0.000	1.000	**15-Sum**	4	39	1.210	0.838
6-Spr	2	24	0.173	0.595	**15-Aut**	4	26	1.102	0.753
6-Sum	2	17	0.606	0.916	**16-Spr**	4	31	0.750	0.529
6-Aut	2	4	0.562	0.877	**16-Sum**	4	22	0.969	0.659
7-Spr	8	69	1.456	0.536	**16-Aut**	3	22	0.843	0.774
7-Sum	2	13	0.666	0.973	**17-Spr**	1	3	0.000	1.000
8-Spr	3	57	0.676	0.655	**17-Sum**	1	12	0.000	1.000
8-Sum	3	32	1.061	0.963	**18-Spr**	1	8	0.000	1.000
8-Aut	3	31	0.457	0.527	**18-Sum**	1	19	0.000	1.000
9-Spr	1	21	0.000	1.000	**18-Aut**	1	1	0.000	1.000
9-Sum	1	6	0.000	1.000	**19-Spr**	1	3	0.000	1.000
9-Aut	1	22	0.000	1.000	**19-Sum**	1	15	0.000	1.000
10-Spr	4	49	0.960	0.653	**20-Spr**	4	12	1.199	0.829
10-Sum	4	36	1.117	0.764	**20-Sum**	4	27	1.311	0.927
11-Spr	1	2	0.000	1.000	**20-Aut**	1	10	0.000	1.000

Spr: Spring, Sum: Summer, Aut: Autumn

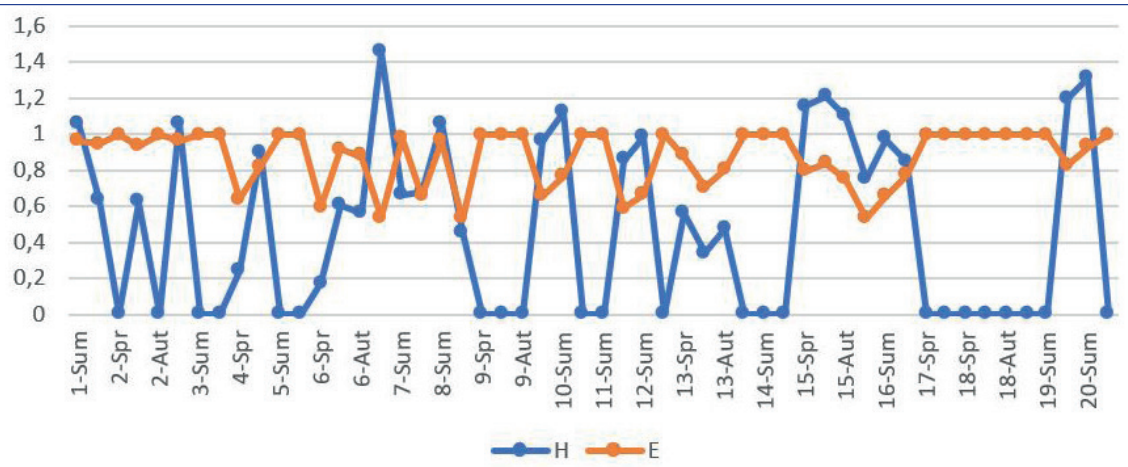

Figure 2. SHE diversity analysis graph of the stations (Spr: Spring, Sum: Summer, Aut: Autumn).

ined, it is seen that the stations have high quality water (Class I) or moderate polluted water (Class II) quality. As a matter of fact, as a result of the evaluation of the obtained physicochemical data and biological findings, it was seen that the physicochemical and biological water quality data showed parallelism.

Although the most important threat affecting the abundance and diversity of the members of the order Ephemeroptera, which is known as an indicator of clean water, is pollution, it is also known that the members of this order do not have tolerance to the decrease in the amount of dissolved oxygen and increasing

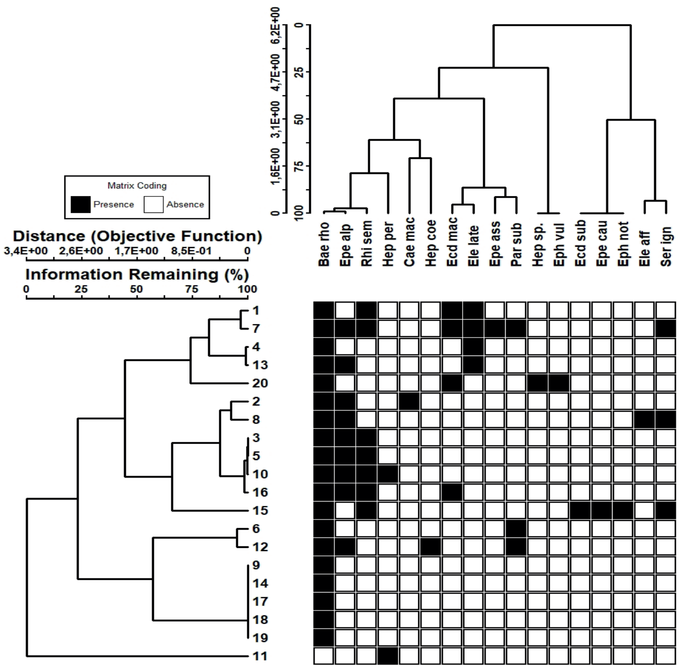

Figure 3. Two-way Cluster Dendogram (Bray-Curtis) of station similarities.

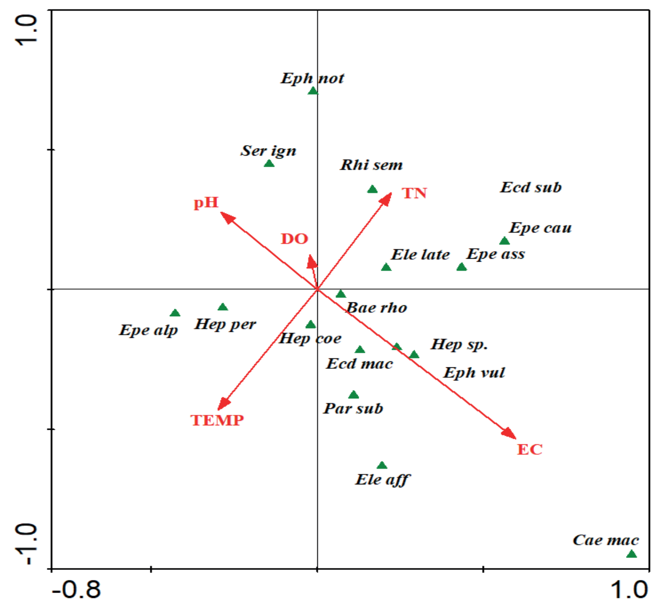

Figure 4. Canonical Correspondence Analysis between Ephemeroptera species and physicochemical parameters [▲: Species, TN: Total Nitrogen, EC: Electrical Conductivity, DO: Dissolved Oxygen, TEMP: Temperature, Bae rho: *Baetis rhodani*, Cae mac: *Caenis macrura*, Ecd mac: *Ecdyonurus macani*, Ecd sub: *Ecdyonurus submontanus*, Ele aff: *Electrogena affinis*, Ele lat: *Electrogena lateralis*, Epe alp: *Epeorus alpicola*, Epe ass: *Epeorus assimilis*, Epe cau: *Epeorus caucasicus*, Hep coe: *Heptagenia coerulans*, Hep fla: *Heptagenia perflava*, Hep sem: *Heptagenia* sp., Rhi sem: *Rhithrogena semicolorata*, Par sub: *Paraleptophlebia submarginata*, Eph vul: *Ephemera vulgata*, Ser ign: *Serratella ignita*, Eph not: *Ephemerella notata*].

pollution due to the increase in the organic matter input in the environment (Kazancı et al., 1997; Demir, 2005; Jandry et al., 2014). Ephemeroptera larvae of O_2 consumption is associated with the water temperature in the aquatic environment and increases depending on the increase in temperature. This situation creates serious threats in terms of species in the environment. In our study; seasonally, the temperature values between stations do not fall below 25 °C and vary between 8.2 and 22.6 °C. Likewise, pH, which is one of the most important variables reflecting the chemical composition and efficiency of water, is in the range of 7.36-8.91 at all stations, and it is seen that it contains reference values belonging to the high water quality class. Aquatic creatures adapt optimally to pH values between 5-9 in their environment; it is known that the productivity of acidic waters is low, while alkaline waters are high. In addition, there is a positive relationship between the mineral ratio and pH in aquatic environments (Ölmez & Saraç, 2009). The highly mineralized structure of all stations except the 8th, 9th, 11th, 12th, 13th and 14th stations supports this situation. The lowest pH in the studied stations belongs to the measurements in the autumn period. This can be explained by the decrease in the pH level due to the decrease in water in the autumn period. As a result, it can be said that the waters are of good quality in terms of temperature, dissolved oxygen, total nitrogen and pH parameters, the amount of organic matter and vegetation rate in the waters is low, and therefore eutrophication is low.

Values related to electrical conductivity, which express the capacity of water to conduct electric current, are in parallel with the temperature value and have been determined as one of the determining parameters affecting the distribution of taxa in the CCA diagram. According to the Pearson correlation analysis, although a positive relationship was observed between electrical conductivity and temperature, a high value was not reached. This is due to the fact that the temperature variable does not reach very high values in three seasons. At the same time, the ground structure is another factor that changes the electrical conductivity (EPA, 2006). In our study, the fact that the stations did not exhibit any sediment properties other than rocks, stones, gravel and coarse sand, the water temperature was below 25 °C and the dissolved oxygen values did not fall below 6, supports the low electrical conductivity and therefore the good water quality in terms of this parameter.

Baetis rhodani, a member of the Baetidae family, which has a cosmopolitan distribution in the worldwide and is known for its high population in aquatic systems, is also widely used as biological indicators of water quality (Williams et al., 2006). As a result of the study, this species was found in all stations except the 11th station and was observed in all seasons with a total of 602 individuals. Percentage frequency values of the stations for the spring, summer and autumn periods were calculated as 90, 85 and 65, respectively. It has been stated that this species is euriterm and also prefers regions with high and medium currents (Buffagni et al., 2009). There are records in many regions including western and eastern Turkiye (Küçüker, 2019). In some studies, it has been stated that this species is found in water quality steps I, II and III, it is observed in rivers every season and it is a common and pollution-tolerant species (Sladeck, 1973; Mısıroğlu, 1995; Tonguç, 2004). As a matter of fact, the fact that it is located very close to the center in the obtained CCA diagram and its high tolerance to variables supports the result of the prevalence of this species. It is also known that the optimum temperature for the reproduction and survival of this species varies between 3 °C and 22 °C (Elliot, 1972). Accordingly, the stream temperatures at all sampling stations show the appropriate temperature ranges for the *B. rhodani* species with the highest abundance.

Among the order Ephemeroptera, the other family with the highest tolerance to organic pollution is Caenidae (Bargos et al., 1990; Timm, 1997; Grandjean et al., 2011). Although species belonging to the genus *Caenis* belonging to this family are found in all river types, they are generally distributed in areas with sandy, loam or gravelly ground structure and slow flowing and sometimes even stagnant waters (Malzacher, 1986). In this study, the *C. macrura* species was found only in the second station belonging to the autumn period. Looking at the CCA diagram, it is seen that this type is located at a separate point.

The Heptageniidae family, which includes the indicator species of unpolluted and undisturbed environments, is the family with the highest diversity in the sampled stations and is represented by five genera and 11 species (*E. macani, E. submontanus, E. affinis, E. lateralis, E. alpicola, E. assimilis, E caucasicus, H. coerulans, H. perflava, Heptagenia sp.* ve *R. semicolorata*). Species belonging to this family generally prefer very clean or lightly polluted xenosaprobic and oligosaprobic stream zones. Rarely, they can also be found in beta-mesosaprobic environments (Hellawell 1986, Hilsenhoff 1988, Kazancı 2001a, Bauernfeind & Humpesch 2001, Bauernfeind et al., 2002). Therefore, they constitute an important group used as clean water indicators in water quality studies (Kazancı et al., 2014). In the study, *E. alpicola*, which was seen at the 2nd, 3rd, 5th, 7th, 8th, 10th, 12th, 13th and 16th stations and was examined with a total of 151 individuals, was determined as the second most common taxon after *B. rhodani* with the frequency values of 40%, 30 and 10% in the spring, summer and autumn periods, respectively. It is known that this species, which is known to have a very low tolerance to organic pollution, prefers cold waters in terms of temperature and is known to spread in high flow waters rich in oxygen (Braasch & Jacob, 1976; Elliot et al., 1988). In the correlation of the obtained CCA diagram, it was seen that this species was in a negative relationship with the total nitrogen variable representing eutrophic conditions, and positively with dissolved oxygen representing clean conditions. Considering the other species of *Epeorus* genus, *E. assimilis* was observed only in the 7th station in the spring period, and *E. caucasicus* was observed only in the 15th station in the autumn period. It is known that both species are cold stenothermic creatures, they prefer stony and rocky ground structure with fast currents from the hypocrenon region to the metarhithron region, and their tolerance to pollution is very low (Kazancı, 2001a). *Rhithrogena semicolorata* species were examined with a total of 63 individuals at the 1st, 3rd, 5th, 7th, 10th, 15th and 16th stations and it was determined as the third most common taxon with the frequency values of 30%, 25% and 10% in the spring, summer and autumn periods, respectively. It has been stated that this species is euriterm and also prefers regions with high and medium currents (Buffagni et al., 2009). This species was generally found in most studies conducted in our country (Tonguç, 2004; Zeybek, 2007; Zeybek et al., 2012, 2014). In the obtained CCA diagram, it is positioned in relation to the total nitrogen variable. *Ecdyonurus* larvae are found in fast-flowing parts of streams and in areas with stony and rocky ground. They have a low tolerance for organic pollution (Bauernfeind & Soldan, 2012). *E. macani* belonging to this genus was observed in the 1st, 7th, 16th and 20th stations in the spring and summer seasons, while the *E. submontanus* was observed only in the 15th station in the autumn season. *Electrogena* is a genus that can be found in regions with oligosaprobic and beta-mesosaprobic features (Bauernfeind, 1995). *E. affinis* belonging to this genus was detected only in the 8th station in the autumn period, and for this reason, it is located further away from the other taxa in the CCA diagram. *E. lateralis* was observed in the 4th and 7th stations in the spring period and at the 1st and 13th stations in the autumn period. In the genus *Heptagenia*, three species were detected in the same stations in the spring and summer periods, of which *H. coerulans* was observed at the 12th station, *H. perflava* at the 10th and 11th stations, and *Heptagenia* sp. at the 20th station.

Taxa belonging to the Leptophlebiidae family are generally distributed in stony areas in the hypocrenon and rhithron regions of rivers (Buffagni et al., 2009). While the genus *Paraleptophlebia* is generally found in oligosaprobic regions, it can also be found in betamesosaprobic, xenosaprobic and alpha-mesosaprobic regions with a low probability (Kazancı, 2001a). In our study, *P. submarginata* species belonging to this family, which was found in all seasons, were observed at the 6th, 7th and 12th stations in the spring, at the 6th and 12th stations in the summer, and only at the 6th station in the autumn.

Ephemera vulgata species belonging to the Ephemeridae family, which is known to be tolerant of low oxygen concentration (Aydınlı, 2008), was found only in the 20th station in the spring and summer periods. It has been reported that this species is distributed in oligosaprobic, ethamesosaprobic and alphamesosaprobic regions and has a wide distribution from east to west in our country (Kazancı & Türkmen, 2008). This means that the species has a wide ecological tolerance to pollution. As a matter of fact, it is seen in the obtained CCA diagram that it is positioned in the opposite direction with the dissolved oxygen.

While individuals belonging to the Ephemerellidae family generally prefer stream regions with beta-mesosaprobic features, they can also be found in stream regions with oligosaprobic features. Although very rarely, it is possible to encounter individuals belonging to this family in alpha-mesosaprobic environments (Kazancı et al., 2014). The genus Ephemerella belonging to this family is also generally found in oligosaprobic, rarely betamezosaprobic and alpha-mesosaprobic regions (Kazancı, 2001a). In our study, *S. ignita* species belonging to this family were found in the 7th, 8th and 15th stations in the spring season and at the 8th and 15th stations in the summer season. It is known that individuals of this species have a wide ecological tolerance and spread in all types of rivers (Bauernfeind & Soldan, 2012). *E. notata* taxon was found only at the 15th station in the spring and summer periods. This species is generally known to be an alpha-beta mesosaprobic zone indicator (Kazancı, 2001a). In the obtained CCA diagram, it is seen that it is located at a distant point.

CONCLUSION

When the stream types of the studied stations were examined, it was observed that all stream sediments were mostly rock, stone, gravel and coarse sand, and the stream velocity was high or moderate. In addition, the mineralization structure was found to be high throughout the stations. Although some agricultural and animal husbandry activities have been carried out around the stream, it can be said that this situation does not threaten the physicochemical properties of the stream. On the other hand, the absence of settlements around the stations supports that the streams are also clean in terms of domestic waste pollutants. Therefore, it has been determined that all physicochemical parameters are within reference ranges at a level that will not pose major threats, and that there is no intense pollution pressure from domestic, industrial and agricultural sources that will adversely affect the aquatic system.

Although there is no detailed study to determine the Ephemeroptera fauna in the Ceyhan Basin, from Kahramanmaraş, which is within the borders of the basin; the distribution of *Baetis* sp, *Ephemerella* sp., *Caenis* sp., *Isonychia* sp., *Siphlonurus* sp., and *Rhitrogena* sp. has been reported, and no individuals belonging to the *Isonychia* and *Siphlonurus* genera were found in our study (Kara & Çömlekçioğlu, 2004; Yıldırım, 2006; Ayas & Black, 2014). Apart from these taxa, other taxa identified are new records for the Ceyhan Basin. This study will provide important information about the Ephemeroptera fauna of our country and will be helpful for the aquatic ecosystem studies in the coming years.

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Ethics committee approval: Ethics committee approval was not required.

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